

## V. CONCLUSIONS AND SUGGESTIONS

### 1. Conclusions

Durian shell was found as a potential sorbent to remove Chromium (VI) from contaminated solution. The adsorption capacity of durian shell to Chromium (VI) represented by the maximum adsorption capacity is approximately about 16 mg/g at low pH and about 6 mg/g at higher pH.

Both Langmuir and Freundlich models represent the adsorption equilibria data quite-well. While for the kinetic studies, pseudo-second order kinetic model gave better correlation for kinetic data in comparison to pseudo first-order model. From thermodynamic studies, were found that the sorption process run spontaneously, endothermic and irreversible.

The biosorption process of Chromium (VI) on durian shell is dominated by chemical sorption.

### 2. Suggestions

The studies of biosorption process of Chromium (VI) using durian shell need further experiments like chemical treatment on durian shell to improve the adsorption capacity of durian shell and to regenerate the durian shell after used as the adsorbent, so it is more economical to use in wastewater treatment.

## **BIBLIOGRAPHY**

## BIBLIOGRAPHY

1. Han, X., et al., *Biosorption and bioreduction of Cr(VI) by a microalgal isolate, Chlorella miniata*. Journal of Hazardous Materials, 2007. **146**: p. 65-72.
2. Srivastava, S. and I.S. Thakur, *Biosorption Potency of Aspergillus niger for Removal of Chromium (VI)*. Current Microbiology, 2006. **53**: p. 232-237.
3. Bishnoi, N.R., et al., *Biosorption of Cr(III) from aqueous solution using algal biomass spirogyra spp.* journal of Hazardous Materials, 2007. **145**: p. 142-147.
4. Ziagova, M., et al., *Comparative study of Cd(II) and Cr(VI) biosorption on Staphylococcus xylosus and Pseudomonas sp. in single and binary mixtures*. Bioresource Technology, 2007. **98**: p. 2859-2865.
5. Dakiky, M., et al., *Selective adsorption of chromium(VI) in industrial wastewater using low-cost abundantly available adsorbents*. Advances in Environmental Research, 2002. **6**(4): p. 533-540.
6. Malkoc, E. and Y. Nuhoglu, *Determination of kinetic and equilibrium parameters of the batch adsorption of Cr(VI) onto waste acorn of Quercus ithaburensis*. Chemical Engineering and Processing, 2007. **46**: p. 1020-1029.
7. Das, S.K. and A.K. Guha, *Biosorption of chromium by Termitomyces clypeatus*. Colloids and Surfaces, 2007. **60**: p. 46-54.
8. Kumar, R., et al., *Biosorption of chromium(VI) from aqueous solution and electroplating wastewater using fungal biomass*. Chemical Engineering Journal, 2008. **135**: p. 202-208.
9. Gokhale, S.V., K.K. Jyoti, and S.S. Lele, *Kinetics and equilibrium modeling of chromium (VI) biosorption on fresh and spent Spirulina platensis/ Chlorella vulgaris biomass*. Bioresource Technology, 2008. **99**: p. 3600-3608.
10. Chergui, A., et al., *Simultaneous biosorption of  $\text{Cu}^{2+}$ ,  $\text{Zn}^{2+}$  and  $\text{Cr}^{6+}$  from aqueous solution by Streptomyces rimosus biomass*. Desalination, 2007. **206**: p. 179-184.
11. Mungasavalli, D.P., T. Viraraghavan, and Y.C. Jin, *Biosorption of chromium from aqueous solutions by pretreated Aspergillus niger: Batch and column studies*. Colloids and Surfaces a-Physicochemical and Engineering Aspects, 2007. **301**(1-3): p. 214-223.
12. Kang, S.Y., J.U. Lee, and K.W. Kim, *Biosorption of Cr(III) and Cr(VI) onto the cell surface of Pseudomonas aeruginosa*. Biochemical Engineering Journal, 2007. **36**(1): p. 54-58.
13. Preetha, B. and T. Viruthagiri, *Batch and continuous biosorption of chromium(VI) by Rhizopus arrhizus*. Separation and Purification Technology, 2007. **57**: p. 126-133.
14. Agarwal, G.S., H.K. Bhuptawat, and S. Chaudhari, *Biosorption of aqueous chromium(VI) by Tamarindicus indica seeds*. Bioresource Technology, 2006. **97**: p. 949-956.
15. Srivastava, S. and I.S. Thakur, *Evaluation of biosorption potency of Acinetobacter sp for removal of hexavalent chromium from tannery effluent*. Biodegradation, 2007. **18**: p. 637-646.
16. Zhou, M., et al., *Kinetic and equilibrium studies of Cr(VI) biosorption by dead Bacillus licheniformis biomass*. World Journal of Microbiology & Biotechnology, 2007. **23**(1): p. 43-48.

17. Aksu, Z., et al., *Equilibrium modelling of individual and simultaneous biosorption of chromium(VI) and nickel(II) onto dried activated sludge*. Water Research, 2002. **36**(12): p. 3063-3073.
18. Mohanty, K., et al., *Biosorption of Cr(VI) from aqueous solutions by Eichhornia crassipes*. Chemical Engineering Journal, 2006. **117**(1): p. 71-77.
19. Sag, Y. and Y. Aktay, *Kinetic studies on sorption of Cr(VI) and Cu(II) ions by chitin, chitosan and Rhizopus arrhizus*. Biochemical Engineering Journal, 2002. **12**(2): p. 143-153.
20. Parvathi, K. and R. Nagendran, *Biosorption of chromium from effluent generated in chrome-electroplating unit using Saccharomyces cerevisiae*. Separation Science and Technology, 2007. **42**: p. 625-638.
21. Xu, H. and Y. Liu, *Mechanisms of Cd<sup>2+</sup>, Cu<sup>2+</sup> and Ni<sup>2+</sup> biosorption by aerobic granules*. Separation and Purification Technology, 2008. **58**: p. 400-411.
22. Khambhaty, Y., et al., *Hg(II) removal from aqueous solution by dead fungal biomass of marine Aspergillus niger: Kinetic studies*. Separation Science and Technology, 2008. **43**(5): p. 1221-1238.
23. Pan, J.H., R.X. Liu, and H.X. Tang, *Surface reaction of Bacillus cereus biomass and its biosorption for lead and copper ions*. Journal of Environmental Sciences-China, 2007. **19**(4): p. 403-408.
24. Yu, J.X., et al., *Cystine-modified biomass for Cd(II) and Pb(II) biosorption*. Journal of Hazardous Materials, 2007. **143**(1-2): p. 277-284.
25. Li, H., Li, Z., Liu, T., Xiao, X., Peng, Z., Deng, L., *A novel technology for biosorption and recovery hexavalent chromium by bio-functional magnetic beads*. Bioresource Technology, 2008. **99**: p. 6271-6279.
26. Hanif, M.A., et al., *Ni(II) biosorption by Cassia fistula (Golden Shower) biomass*. Journal of Hazardous Materials, 2007. **139**(2): p. 345-355.
27. Hanif, M.A., et al., *Kinetic studies for Ni(II) biosorption from industrial wastewater by Cassia fistula (Golden Shower) biomass*. Journal of Hazardous Materials, 2007. **145**(3): p. 501-505.
28. Pavasant, P., et al., *Biosorption of Cu<sup>2+</sup>, Cd<sup>2+</sup>, Pb<sup>2+</sup>, and Zn<sup>2+</sup> using dried marine green macroalga caulerpa lentillifera*. Bioresource Technology, 2006. **97**(18): p. 2321-2329.
29. Tunali, S., et al., *Equilibrium and kinetics of biosorption of lead(II) from aqueous solutions by Cephalosporium aphidicola*. Separation and Purification Technology, 2006. **47**(3): p. 105-112.
30. Tuzun, I., et al., *Equilibrium and kinetic studies on biosorption of Hg(II), Cd(II) and Pb(II) ions onto microalgae Chlamydomonas reinhardtii*. Journal of Environmental Management, 2005. **77**(2): p. 85-92.
31. Han, X., et al., *Biosorption and bioreduction of Cr(VI) by a microalgal isolate, Chlorella miniata*. Journal of Hazardous Materials, 2007. **146**(1-2): p. 65-72.
32. Ahalya, N., R.D. Kanamadi, and T.V. Ramachandra, *Biosorption of chromium (VI) from aqueous solutions by the husk of Bengal gram (Cicer arietinum)*. Electronic Journal of Biotechnology, 2005. **8**(3).
33. Deng, L.P., et al., *Biosorption of copper(II) from aqueous solutions by green alga Cladophora fascicularis*. Biodegradation, 2007. **18**(4): p. 393-402.
34. Deng, L.P., et al., *Sorption and desorption of lead (II) from wastewater by green algae Cladophora fascicularis*. Journal of Hazardous Materials, 2007. **143**(1-2): p. 220-225.

35. Liu, R., et al., *Effect of pH on biosorption of boron onto cotton cellulose*. Desalination, 2007. **207**(1-3): p. 257-267.
36. Doshi, H., A. Ray, and I.L. Kothari, *Bioremediation potential of live and dead spirulina: Spectroscopic, kinetics and SEM studies*. Biotechnology and Bioengineering, 2007. **96**(6): p. 1051-1063.
37. Doshi, H., A. Ray, and I.L. Kothari, *Biosorption of cadmium by live and dead Spirulina: IR spectroscopic, kinetics, and SEM studies*. Current Microbiology, 2007. **54**(3): p. 213-218.
38. Wang, X.J., et al., *Biosorption of cadmium(II) and lead(II) ions from aqueous solutions onto dried activated sludge*. Journal of Environmental Sciences-China, 2006. **18**(5): p. 840-844.
39. Ahmady-Asbchin, S., Y. Andres, C. Gerente, and P.L. Cloirec, *Biosorption of Cu(II) from aqueous solution by Fucus serratus: surface characterization and sorption mechanism*. Bioresource Technology, 2008. **99**: p. 6150-6155.
40. Elangovan, R., L. Philip, and K. Chandraraj, *Biosorption of chromium species by aquatic weeds: Kinetics and mechanism studies*. Journal of Hazardous Materials, 2008. **152**(1): p. 100-112.
41. Panda, G.C., S.K. Das, and A.K. Guha, *Biosorption of cadmium and nickel by functionalized husk of Lathyrus sativus*. Colloids and Surfaces B-Biointerfaces, 2008. **62**(2): p. 173-179.
42. Guo, X.Y., S.Z. Zhang, and X.Q. Shan, *Adsorption of metal ions on lignin*. Journal of Hazardous Materials, 2008. **151**(1): p. 134-142.
43. Cukierman, A.L., *Metal ion biosorption potential of lignocellulosic biomasses and marine algae for wastewater treatment*. Adsorption Science & Technology, 2007. **25**: p. 227-244.
44. Kiran, I., T. Akar, and S. Tunali, *Biosorption of Pb(II) and Cu(II) from aqueous solutions by pretreated biomass of Neurospora crassa*. Process Biochemistry, 2005. **40**(11): p. 3550-3558.
45. Salem, Z. and K. Allia, *Cadmium biosorption on vegetal biomass*. International Journal of Chemical Reactor Engineering, 2008. **6**.
46. Dundar, M., C. Nuhoglu, and Y. Nuhoglu, *Biosorption of Cu(II) ions onto the litter of natural trembling poplar forest*. Journal of Hazardous Materials, 2008. **151**(1): p. 86-95.
47. Choi, S.B. and Y.S. Yun, *Biosorption of cadmium by various types of dried sludge: An equilibrium study and investigation of mechanisms*. Journal of Hazardous Materials, 2006. **138**(2): p. 378-383.
48. Komy, Z.R., et al., *Characterisation of acidic sites of Pseudomonas biomass capable of binding protons and cadmium and removal of cadmium via biosorption*. World Journal of Microbiology & Biotechnology, 2006. **22**(9): p. 975-982.
49. Malkoc, E. and Y. Nuhoglu, *Determination of kinetic and equilibrium parameters of the batch adsorption of Cr(VI) onto waste acorn of Quercus ithaburensis*. Chemical Engineering and Processing, 2007. **46**: p. 1020-1029.
50. Bueno, B.Y.M., et al., *Biosorption of lead(II), chromium(III) and copper(II) by R. opacus: Equilibrium and kinetic studies*. Minerals Engineering, 2008. **21**: p. 65-75.
51. Baral, S.S., et al., *Removal of Cr(VI) from aqueous solution using waste weed, Salvinia cucullata*. Chemistry and Ecology, 2007. **23**(2): p. 105-117.
52. Khormaei, M., et al., *Copper biosorption from aqueous solutions by sour orange residue*. Journal of Hazardous Materials, 2007. **149**: p. 269-274.

53. Rao, P.S., et al., *Comparison of biosorption of nickel(II) and copper(II) ions from aqueous solution by Sphaeroplea algae and acid treated Sphaeroplea algae*. Separation Science and Technology, 2005. **40**(15): p. 3149-3165.
54. Gupta, V.K. and A. Rastogi, *Biosorption of lead from aqueous solutions by green algae Spirogyra species: Kinetics and equilibrium studies*. Journal of Hazardous Materials, 2008. **152**(1): p. 407-414.
55. Popuri, S.R., et al., *Biosorption of hexavalent chromium using tamarind (Tamarindus indica) fruit shell - a comparative study*. Electronic Journal of Biotechnology, 2007. **10**: p. 358-367.
56. Malkoc, E. and Y. Nuhoglu, *Investigations of nickel(II) removal from aqueous solutions using tea factory waste*. Journal of Hazardous Materials, 2005. **127**(1-3): p. 120-128.
57. Das, S.K. and A.K. Guha, *Biosorption of chromium by Termitomyces clypeatus*. Colloids and Surfaces B-Biointerfaces, 2007. **60**: p. 46-54.
58. Yu, J.X., et al., *A simple method to prepare poly(amic acid)-modified biomass for enhancement of lead and cadmium adsorption*. Biochemical Engineering Journal, 2007. **33**(2): p. 126-133.
59. Yazici, H., M. Kilic, and M. Solak, *Biosorption of copper(II) by Marrubium globosum subsp globosum leaves powder: Effect of chemical pretreatment*. Journal of Hazardous Materials, 2008. **151**(2-3): p. 669-675.
60. Vasudevan, P., V. Padmavathy, and S.C. Dhingra, *Biosorption of monovalent and divalent ions on baker's yeast*. Bioresource Technology, 2002. **82**(3): p. 285-289.
61. Vasudevan, P., V. Padmavathy, and S.C. Dhingra, *Kinetics of biosorption of cadmium on Baker's yeast*. Bioresource Technology, 2003. **89**(3): p. 281-287.
62. Raize, O., Y. Argaman, and S. Yannai, *Mechanisms of biosorption of different heavy metals by brown marine macroalgae*. Biotechnology and Bioengineering, 2004. **87**(4): p. 451-458.
63. Han, X., Y.S. Wong, and N.F.Y. Tam, *Surface complexation mechanism and modeling in Cr(III) biosorption by a microalgal isolate, Chlorella miniata*. Journal of Colloid and Interface Science, 2006. **303**(2): p. 365-371.
64. Yavuz, H., et al., *Biosorption of mercury on magnetically modified yeast cells*. Separation and Purification Technology, 2006. **52**(2): p. 253-260.
65. Sheng, P.X., et al., *Biosorption of copper by immobilized marine algal biomass*. Chemical Engineering Journal, 2008. **136**(2-3): p. 156-163.
66. Deng, S.B. and Y.P. Ting, *Characterization of PEI-modified biomass and biosorption of Cu(II), Pb(II) and Ni(II)*. Water Research, 2005. **39**(10): p. 2167-2177.
67. Zhou, D., L. Zhang, and S.L. Guo, *Mechanisms of lead biosorption on cellulose/chitin beads*. Water Research, 2005. **39**(16): p. 3755-3762.
68. Kumari, P., et al., *Biosorption studies on shelled Moringa oleifera Lamarck seed powder: Removal and recovery of arsenic from aqueous system*. International Journal of Mineral Processing, 2006. **78**(3): p. 131-139.
69. Garg, U.K., et al., *Removal of hexavalent chromium from aqueous solution by agricultural waste biomass*. Journal of Hazardous Materials, 2007. **140**(1-2): p. 60-68.
70. Isa, M.H., et al., *Removal of chromium (VI) from aqueous solution using treated oil palm fibre*. Journal of Hazardous Materials, 2008. **152**(2): p. 662-668.

71. Ngah, W.S.W. and M. Hanafiah, *Adsorption of copper on rubber (Hevea brasiliensis) leaf powder: Kinetic, equilibrium and thermodynamic studies*. Biochemical Engineering Journal, 2008. **39**(3): p. 521-530.
72. Taty-Costodes, V.C., et al., *Removal of Cd(II) and Pb(II) ions, from aqueous solutions, by adsorption onto sawdust of Pinus sylvestris*. Journal of Hazardous Materials, 2003. **105**(1-3): p. 121-142.
73. Gonzalez-Chavez, C., et al., *Copper sorption and accumulation by the extraradical mycelium of different Glomus spp. (arbuscular mycorrhizal fungi) isolated from the same polluted soil*. Plant and Soil, 2002. **240**(2): p. 287-297.
74. Akar, T., S. Tunali, and I. Kiran, *Botrytis cinerea as a new fungal biosorbent for removal of Pb(II) from aqueous solutions*. Biochemical Engineering Journal, 2005. **25**(3): p. 227-235.
75. Akar, T., S. Tunali, and A. Cabuk, *Study on the characterization of lead (II) biosorption by fungus Aspergillus parasiticus*. Applied Biochemistry and Biotechnology, 2007. **136**(3): p. 389-405.
76. Panda, G.C., et al., *Adsorption of cadmium on husk of Lathyrus sativus: Physico-chemical study*. Colloids and Surfaces B-Biointerfaces, 2006. **50**(1): p. 49-54.
77. Pino, G.H., et al., *Biosorption of heavy metals by powder of green coconut shell*. Separation Science and Technology, 2006. **41**(14): p. 3141-3153.
78. Liu, Y. and H. Xu, *Equilibrium, thermodynamics and mechanisms of Ni<sup>2+</sup> biosorption by aerobic granules*. Biochemical Engineering Journal, 2007. **35**(2): p. 174-182.
79. Majumdar, S.S., et al., *Adsorption behavior of copper ions on Mucor rouxii biomass through microscopic and FTIR analysis*. Colloids and Surfaces B-Biointerfaces, 2008. **63**(1): p. 138-145.
80. Basha, S., Z.V.P. Murthy, and B. Jha, *Sorption of Hg(II) from aqueous solutions onto Carica papaya: Application of isotherms*. Industrial & Engineering Chemistry Research, 2008. **47**: p. 980-986.
81. Chen, C. and J.L. Wang, *Investigating the interaction mechanism between zinc and Saccharomyces cerevisiae using combined SEM-EDX and XAFS*. Applied Microbiology and Biotechnology, 2008. **79**(2): p. 293-299.
82. Srivastava, S. and I.S. Thakur, *Biosorption potency of Aspergillus niger for removal of chromium (VI)*. Current Microbiology, 2006. **53**(3): p. 232-237.
83. Pethkar, A.V., S.K. Kulkarni, and K.M. Paknikar, *Comparative studies on metal biosorption by two strains of Cladosporium cladosporioides*. Bioresource Technology, 2001. **80**(3): p. 211-215.
84. Sheng, P.X., et al., *Sorption of lead, copper, cadmium, zinc, and nickel by marine algal biomass: characterization of biosorptive capacity and investigation of mechanisms*. Journal of Colloid and Interface Science, 2004. **275**(1): p. 131-141.
85. Park, D., et al., *Mechanism of hexavalent chromium removal by dead fungal biomass of Aspergillus niger*. Water Research, 2005. **39**(4): p. 533-540.
86. Deng, L.P., et al., *Biosorption of copper (II) and lead (II) from aqueous solutions by nonliving green algae Cladophora fascicularis: Equilibrium, kinetics and environmental effects*. Adsorption-Journal of the International Adsorption Society, 2006. **12**(4): p. 267-277.

87. Yu, J.X., et al., *Biomass grafted with polyamic acid for enhancement of cadmium(II) and lead(II) biosorption*. *Reactive & Functional Polymers*, 2007. **67**(6): p. 564-572.
88. Tong, M., et al., *Polymer modified biomass of baker's yeast for treating simulated wastewater containing nickel and lead*. *Polymers for Advanced Technologies*, 2007. **18**: p. 829-834.
89. Sun, F.Q. and Z.Z. Shao, *Biosorption and bioaccumulation of lead by *Penicillium* sp Psf-2 isolated from the deep sea sediment of the Pacific Ocean*. *Extremophiles*, 2007. **11**: p. 853-858.
90. Lin, Z., Zhou, C., Wu, J., Zhou, J., Wang, L., *A further insight into the mechanism of Ag<sup>+</sup> biosorption by *Lactobacillus* sp. strain A09*. *Spectrochimica Acta Part A*, 2005. **61**: p. 1195-1200.
91. Wibowo, N., et al., *Adsorption of benzene and toluene from aqueous solutions onto activated carbon and its acid and heat treated forms: Influence of surface chemistry on adsorption*. *Journal of Hazardous Materials*, 2007. **146**(1-2): p. 237-242.
92. Southichak, B., et al., *Pb(II) biosorption on reed biosorbent derived from wetland: effect of pretreatment on functional groups*. *Water Science and Technology*, 2006. **54**(10): p. 133-141.
93. Aydin, H., Y. Buluta, and C. Yerlikaya, *Removal of copper (II) from aqueous solution by adsorption onto low-cost adsorbents*. *Journal of Environmental Management*, 2008. **87**(1): p. 37-45.
94. Guzel, F., H. Yakut, and G. Topal, *Determination of kinetic and equilibrium parameters of the batch adsorption of Mn(II), Co(II), Ni(II) and Cu(II) from aqueous solution by black carrot (*Daucus carota* L.) residues*. *Journal of Hazardous Materials*, 2008. **153**(3): p. 1275-1287.
95. Pagnanelli, F., et al., *Heavy metal removal by olive pomace: biosorbent characterisation and equilibrium modelling*. *Chemical Engineering Science*, 2003. **58**(20): p. 4709-4717.
96. Fiol, N., et al., *Sorption of Pb(II), Ni(II), Cu(II) and Cd(II) from aqueous solution by olive stone waste*. *Separation and Purification Technology*, 2006. **50**(1): p. 132-140.
97. Hammamni, A., et al., *Biosorption of heavy metals by activated sludge and their desorption characteristics*. *Journal of Environmental Management*, 2007. **84**(4): p. 419-426.
98. Yuncu, B., F.D. Sanin, and U. Yetis, *An investigation of heavy metal biosorption in relation to C/N ratio of activated sludge*. *Journal of Hazardous Materials*, 2006. **137**(2): p. 990-997.
99. Zafar, S., F. Aqil, and Q. Ahmad, *Metal tolerance and biosorption potential of filamentous fungi isolated from metal contaminated agricultural soil*. *Bioresource Technology*, 2007. **98**(13): p. 2557-2561.
100. Dahiya, S., R.M. Tripathi, and A.G. Hegde, *Biosorption of heavy metals and radionuclide from aqueous solutions by pre-treated arca shell biomass*. *Journal of Hazardous Materials*, 2008. **150**: p. 376-386.
101. Romera, E., et al., *Comparative study of biosorption of heavy metals using different types of algae*. *Bioresource Technology*, 2007. **98**: p. 3344-3353.
102. Kumar, R., et al., *Biosorption of chromium(VI) from aqueous solution and electroplating wastewater using fungal biomass*. *Chemical Engineering Journal*, 2008. **135**: p. 202-208.



103. Parvathi, K., R. Nareshkumar, and R. Nagendran, *Biosorption of manganese by Aspergillus niger and Saccharomyces cerevisiae*. World Journal of Microbiology & Biotechnology, 2007. **23**(5): p. 671-676.
104. Dursun, A.Y., *A comparative study on determination of the equilibrium, kinetic and thermodynamic parameters of biosorption of copper(II) and lead(II) ions onto pretreated Aspergillus niger*. Biochemical Engineering Journal, 2006. **28**(2): p. 187-195.
105. Mukhopadhyay, M., S.B. Noronha, and G.K. Suraishkumar, *Kinetic modeling for the biosorption of copper by pretreated Aspergillus niger biomass*. Bioresource Technology, 2007. **98**(9): p. 1781-1787.
106. Matheickal, J.T. and Q.M. Yu, *Biosorption of lead(II) and copper(II) from aqueous solutions by pre-treated biomass of Australian marine algae*. Bioresource Technology, 1999. **69**(3): p. 223-229.
107. Ruiz, C.G., Tirado, V.R., Gil, B.G., *Cadmium and zinc removal from aqueous solutions by Bacillus jeotgali: pH, salinity and temperature effects*. Bioresource Technology, 2008. **99**: p. 3864-3870.
108. Al-Rub, F.A.A., et al., *Biosorption of copper on Chlorella vulgaris from single, binary and ternary metal aqueous solutions*. Process Biochemistry, 2006. **41**(2): p. 457-464.
109. Aksu, Z. and G. Donmez, *Binary biosorption of cadmium(II) and nickel(II) onto dried Chlorella vulgaris: Co-ion effect on mono-component isotherm parameters*. Process Biochemistry, 2006. **41**(4): p. 860-868.
110. Gokhale, S.V., K.K. Jyoti, and S.S. Lele, *Kinetic and equilibrium modeling of chromium (VI) biosorption on fresh and spent Spirulina platensis/Chlorella vulgaris biomass*. Bioresource Technology, 2008. **99**(9): p. 3600-3608.
111. Anjana, K., et al., *Biosorption of Cr(VI) by immobilized biomass of two indigenous strains of cyanobacteria isolated from metal contaminated soil*. Journal of Hazardous Materials, 2007. **148**(1-2): p. 383-386.
112. Onal, S., S.H. Baysal, and G. Ozdemir, *Studies on the applicability of alginate-entrapped Chryseomonas luteola TEM 05 for heavy metal biosorption*. Journal of Hazardous Materials, 2007. **146**(1-2): p. 417-420.
113. Ekmekyapar, F., et al., *Biosorption of copper(II) by nonliving lichen biomass of Cladonia rangiformis hoffm*. Journal of Hazardous Materials, 2006. **137**(1): p. 293-298.
114. Ho, Y.S. and A.E. Ofomaja, *Biosorption thermodynamics of cadmium on coconut copra meal as biosorbent*. Biochemical Engineering Journal, 2006. **30**(2): p. 117-123.
115. Ofomaja, A.E. and Y.S. Ho, *Effect of pH on cadmium biosorption by coconut copra meal*. Journal of Hazardous Materials, 2007. **139**(2): p. 356-362.
116. Vijayaraghavan, K., K. Palanivelu, and M. Velan, *Biosorption of copper(II) and cobalt(II) from aqueous solutions by crab shell particles*. Bioresource Technology, 2006. **97**(12): p. 1411-1419.
117. Chen, W.M., et al., *Metal biosorption capability of Cupriavidus taiwanensis and its effects on heavy metal removal by nodulated Mimosa pudica*. Journal of Hazardous Materials, 2008. **151**(2-3): p. 364-371.
118. Ozer, A., et al., *Investigation of nickel(II) biosorption on Enteromorpha prolifera: Optimization using response surface analysis*. Journal of Hazardous Materials, 2008. **152**(2): p. 778-788.

119. Ansari, M.I. and A. Malik, *Biosorption of nickel and cadmium by metal resistant bacterial isolates from agricultural soil irrigated with industrial wastewater*. Bioresource Technology, 2007. **98**(16): p. 3149-3153.
120. Ghodbane, I., et al., *Kinetic and equilibrium study for the sorption of cadmium(II) ions from aqueous phase by eucalyptus bark*. Journal of Hazardous Materials, 2008. **152**(1): p. 148-158.
121. Eseudero, C., et al., *Effect of EDTA on divalent metal adsorption onto grape stalk and exhausted coffee wastes*. Journal of Hazardous Materials, 2008. **152**(2): p. 476-485.
122. Pal, A., S. Ghosh, and A.K. Paul, *Biosorption of cobalt by fungi from serpentine soil of Andaman*. Bioresource Technology, 2006. **97**(10): p. 1253-1258.
123. Pino, G.H., et al., *Biosorption of cadmium by green coconut shell powder*. Minerals Engineering, 2006. **19**(5): p. 380-387.
124. Demirbas, E., et al., *Removal of Ni(II) from aqueous solution by adsorption onto hazelnut shell activated carbon: equilibrium studies*. Bioresource Technology, 2002. **84**(3): p. 291-293.
125. Iqbal, M., A. Saeed, and S.I. Zafar, *Hybrid biosorbent: An innovative matrix to enhance the biosorption of Cd(II) from aqueous solution*. Journal of Hazardous Materials, 2007. **148**(1-2): p. 47-55.
126. Bunluesin, S., et al., *Batch and continuous packed column studies of cadmium biosorption by Hydrilla verticillata Biomass*. Journal of Bioscience and Bioengineering, 2007. **103**(6): p. 509-513.
127. Hasan, S.H., et al., *Removal of Cr(VI) from aqueous solutions using agricultural waste 'maize bran'*. Journal of Hazardous Materials, 2008. **152**(1): p. 356-365.
128. Al-Anber, Z.A. and M.A.D. Matouq, *Batch adsorption of cadmium ions from aqueous solution by means of olive cake*. Journal of Hazardous Materials, 2008. **151**(1): p. 194-201.
129. Xuan, Z.X., et al., *Study on the equilibrium, kinetics and isotherm of biosorption of lead ions onto pretreated chemically modified orange peel*. Biochemical Engineering Journal, 2006. **31**(2): p. 160-164.
130. Abu Al-Rub, F.A., *Biosorption of zinc on palm tree leaves: Equilibrium, kinetics, and thermodynamics studies*. Separation Science and Technology, 2006. **41**(15): p. 3499-3515.
131. Ho, Y.S. and A.E. Ofomaja, *Pseudo-second-order model for lead ion sorption from aqueous solutions onto palm kernel fiber*. Journal of Hazardous Materials, 2006. **129**(1-3): p. 137-142.
132. Wang, X.S., Y. Qin, and Z.F. Li, *Biosorption of zinc from aqueous solutions by rice bran: Kinetics and equilibrium studies*. Separation Science and Technology, 2006. **41**(4): p. 747-756.
133. Bahadir, T., et al., *The investigation of lead removal by biosorption: An application at storage battery industry wastewaters*. Enzyme and Microbial Technology, 2007. **41**(1-2): p. 98-102.
134. Parvathi, K. and R. Nagendran, *Biosorption of chromium from effluent generated in chrome-electroplating unit using Saccharomyces cerevisiae*. Separation Science and Technology, 2007. **42**(3): p. 625-638.
135. Vinopal, S., T. Ruml, and P. Kotrba, *Biosorption of Cd<sup>2+</sup> and Zn<sup>2+</sup> by cell surface-engineered Saccharomyces cerevisiae*. International Biodeterioration & Biodegradation, 2007. **60**(2): p. 96-102.

136. Naddafi, K., et al., *Biosorption of lead(II) and cadmium(II) by protonated Sargassum glaucescens biomass in a continuous packed bed column*. Journal of Hazardous Materials, 2007. **147**(3): p. 785-791.
137. Esposito, A., F. Pagnanelli, and F. Veglio, *pH-related equilibria models for biosorption in single metal systems*. Chemical Engineering Science, 2002. **57**(3): p. 307-313.
138. Gupta, V.K., et al., *Biosorption of copper(II) from aqueous solutions by Spirogyra species*. Journal of Colloid and Interface Science, 2006. **296**(1): p. 59-63.
139. Chergui, A., et al., *Simultaneous biosorption of Cu<sup>2+</sup>, Zn (2+) and Cr<sup>6+</sup> from aqueous solution by Streptomyces rimosus biomass*. Desalination, 2007. **206**(1-3): p. 179-184.
140. Malkoc, E. and Y. Nuhoglu, *Potential of tea factory waste for chromium(VI) removal from aqueous solutions: Thermodynamic and kinetic studies*. Separation and Purification Technology, 2007. **54**(3): p. 291-298.
141. Malkoc, E. and Y. Nuhoglu, *Removal of Ni(II) ions from aqueous solutions using waste of tea factory: Adsorption on a fixed-bed column*. Journal of Hazardous Materials, 2006. **135**(1-3): p. 328-336.
142. Amarasinghe, B. and R.A. Williams, *Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater*. Chemical Engineering Journal, 2007. **132**(1-3): p. 299-309.
143. Sari, A. and M. Tuzen, *Biosorption of Pb(II) and Cd(II) from aqueous solution using green alga (Ulva lactuca) biomass*. Journal of Hazardous Materials, 2008. **152**(1): p. 302-308.
144. Wang, H.L. and C. Chen, *Biosorption of heavy metals by Saccharomyces cerevisiae: A review*. Biotechnology Advances, 2006. **24**(5): p. 427-451.
145. Das, S.K., A.R. Das, and A.K. Guha, *A study on the adsorption mechanism of mercury on Aspergillus versicolor biomass*. Environmental Science & Technology, 2007. **41**: p. 8281-8287.
146. Bishnoi, N.R., et al., *Biosorption of Cr(III) from aqueous solution using algal biomass spirogyra spp*. Journal of Hazardous Materials, 2007. **145**(1-2): p. 142-147.
147. Benguella, B. and H. Benaissa, *Cadmium removal from aqueous solutions by chitin: kinetic and equilibrium studies*. Water Research, 2002. **36**(10): p. 2463-2474.
148. Shen, J.C. and Z. Duvnjak, *Effects of temperature and pH on adsorption isotherms for cupric and cadmium ions in their single and binary solutions using corncob particles as adsorbent*. Separation Science and Technology, 2004. **39**(13): p. 3023-3041.
149. Ho, Y.S., *Isotherms for the sorption of lead onto peat: Comparison of linear and non-linear methods*. Polish Journal of Environmental Studies, 2006. **15**(1): p. 81-86.
150. Uslu, G. and M. Tanyol, *Equilibrium and thermodynamic parameters of single and binary mixture biosorption of lead(II) and copper(II) ions onto Pseudomonas putida: Effect of temperature*. Journal of Hazardous Materials, 2006. **135**(1-3): p. 87-93.
151. Erenturk, S. and E. Malkoc, *Removal of lead(II) by adsorption onto Viscum album L.: Effect of temperature and equilibrium isotherm analyses*. Applied Surface Science, 2007. **253**(10): p. 4727-4733.

152. Padmavathy, V., *Biosorption of nickel(II) ions by baker's yeast: Kinetic, thermodynamic and desorption studies*. Bioresource Technology, 2008. **99**(8): p. 3100-3109.
153. Romero-Gonzalez, M.E., C.J. Williams, and P.H.E. Gardiner, *Study of the mechanisms of cadmium biosorption by dealginated seaweed waste*. Environmental Science & Technology, 2001. **35**(14): p. 3025-3030.
154. Tan, T.W. and P. Cheng, *Biosorption of metal ions with Penicillium chrysogenum*. Applied Biochemistry and Biotechnology, 2003. **104**(2): p. 119-128.
155. Cho, D.H., Kim, E.Y., *Characterization of Pb(II) biosorption from aqueous solution by Rhodotorula glutinis*. Bioprocess Biosyst. Eng., 2003. **25**: p. 271-277.
156. Deng, S.B. and Y.P. Ting, *Polyethylenimine-modified fungal biomass as a high-capacity biosorbent for Cr(VI) anions: Sorption capacity and uptake mechanisms*. Environmental Science & Technology, 2005. **39**(21): p. 8490-8496.
157. Panda, G.C., et al., *Adsorption of nickel on husk of Lathyrus sativus: Behavior and binding mechanism*. Colloids and Surfaces B-Biointerfaces, 2007. **57**(2): p. 135-142.
158. Altun, T. and E. Pehlivan, *Removal of copper(II) ions from aqueous solutions by walnut-, hazelnut- and almond-shells*. Clean-Soil Air Water, 2007. **35**: p. 601-606.
159. Gode, F., E.D. Atalay, and E. Pehlivan, *Removal of Cr(VI) from aqueous solutions using modified red pine sawdust*. Journal of Hazardous Materials, 2008. **152**(3): p. 1201-1207.
160. Levine, I.N., Physical Chemistry fifth edition 2002, New York: McGraw Hill.
161. Chandra, T.C., et al., *Adsorption of basic dye onto activated carbon prepared from durian shell: Studies of adsorption equilibrium and kinetics*. Chemical Engineering Journal, 2007.